Beam Loss Monitor Upgrade

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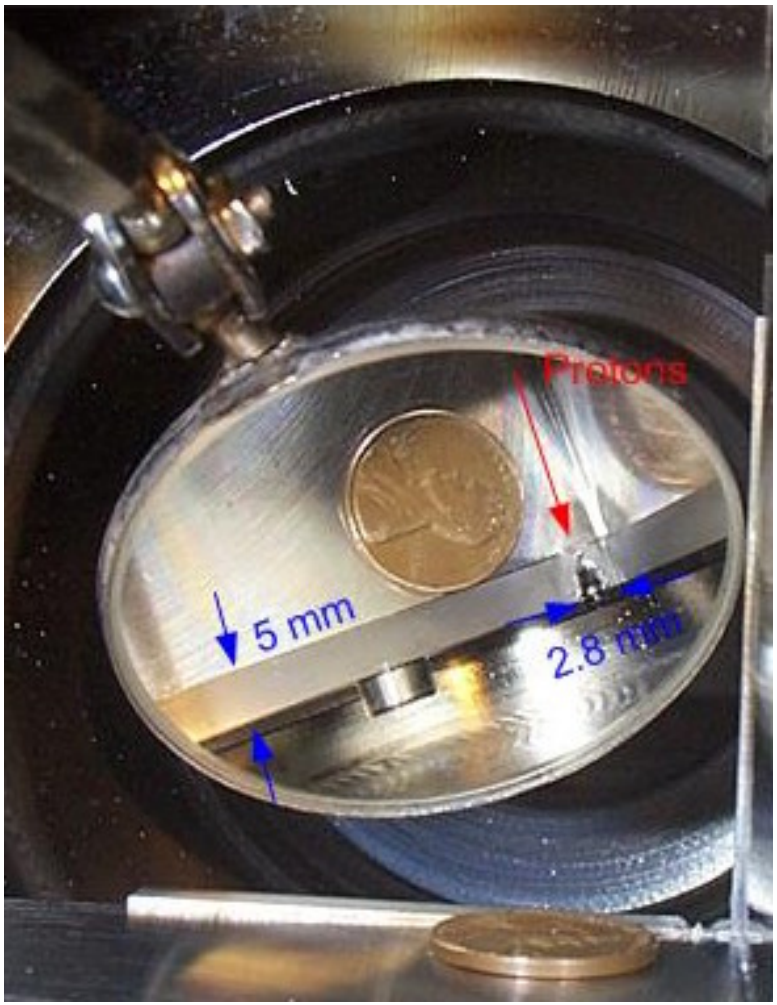
All Experimenters' Meeting

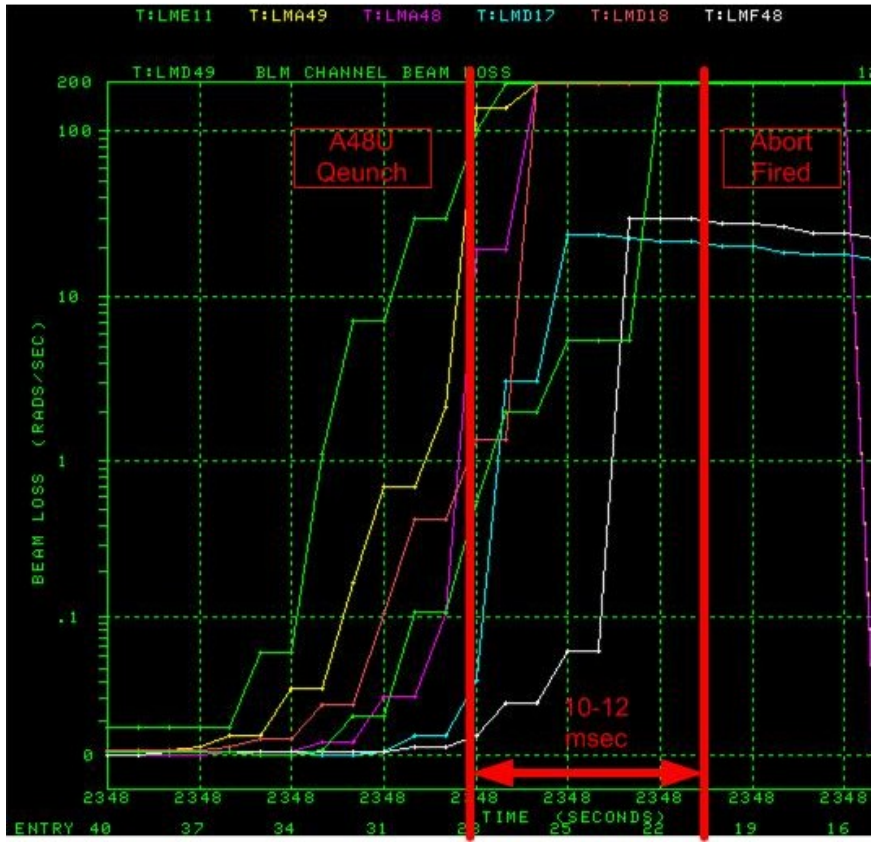
2 May 2005

Motivation

- **Don't do this again.**



Loss profile: Tokyo-pot 16-house quench



Response: Abort Upgrade

- **New Loss Monitor electronics**
  - **Abort logic designed for collider operations**
  - **Improved diagnostic capabilities**
- **Improvements to QPM**
  - **Faster response**
  - **Running many months**
  - **Ask the Tevatron guys for details**

Further Motivation

- **Scope broadened to improve high-intensity proton operations**
- **Tevatron**
  - **Protect magnets from beam-induced quenches**
  - **Legacy system is not sufficiently flexible to use during complex operations cycle**
    - Designed for fast-cycle fixed-target operations
- **Main Injector**
  - **Greater diagnostic capability needed for high-intensity operation**
    - Limit activation of accelerator components
    - Intensity 5x greater with NUMI operation
    - Maximize proton flux
- **Booster**
  - **Improved diagnostics**
    - Limit activation
    - Maximize flux

Existing System Characteristics and Limitations

- **Signal properties**
  - **Good resolution and dynamic range**
  - **Fast leading edge response, slow discharge**
- **Tevatron Aborts**
  - **Fast: ~ 50-100 μs**
  - **Fires on single channel over threshold**
  - **Minimal compatibility with multiple machine configurations**
    - Two abort levels, high and low field
    - Abort disabled when antiprotons are in the machine
- **Read out**
  - **Updates slowly: ~ 3 ms period**
  - **Fast access to one channel per chassis**
    - 24 signals multiplexed in MI
- **Difficult to enhance and maintain**
  - **23 years old**
  - **Read out via Multibus(!) with obsolete software**

Requirements for New System

- **Robustness: No false aborts**
- **Reliability: No missed aborts**
- **Respond to changing machine configurations**
- **Access to data from all channels**
- **Maintain resolution**
  - **System designed around low-noise integrator**
- **Large dynamic range**
  - **0.02 Rad/s in 1 ms to 100 Rad in a single turn**
- **Good time resolution and depth**
  - **Multiple integration periods, each with >4k sample history**
- **Include experiments in Tevatron BLM system**
  - **Two Camac crates with special electronics hard to maintain**

System Overview

- **Integrate BLM current and digitize every ~20 μs**
  - **Tevatron turn frequency or MI frequency ÷2**
- **Form three running sums for additional integration periods**
  - **Programmable time constants**
    - Example: 1ms, 50ms, 1s
  - **Maintain history of >4000 cycles for each period**
    - Also 8k injection turn-by-turn
  - **Also record integrated loss through each MI cycle**
- **One abort threshold per integration period for each channel**
- **Abort requirements changed in response to machine states**
  - **Thresholds, masks, multiplicities**
- **Safe operation**
  - **Isolated from VME and Ethernet**
    - Embedded microprocessor
    - Custom local bus on J2

Components

- **Digitizer Card**
  - **4 integrator channels**
    - Deadtimeless operation
  - **Form running sums**
  - **Compare to thresholds**
  - **Raw data buffers**
  - **Max 15 per crate**
- **Timing Card**
  - **Provides synchronous clock**
  - **Keeps time buffers**
  - **Decodes machine clock events**
- **High Voltage Card**
  - **Power up to 60 channels**
- **Control Card**
  - **Keeps diagnostic data**
    - Running sum data
  - **Updates abort requirements on state changes**
- **Abort Card**
  - **Reads abort data from Digitizers**
  - **Compares to mask and multiplicity requirement**
- **Crate**
  - **Wiener 6U VME chassis**
  - **Low-noise power supply**
  - **Custom J2 backplane**

Status

- **Digitizer**
  - **Extensive standalone testing of prototype**
  - **Updating design to extend functionality**
- **Timing Card**
  - **Testing prototype**
- **Crate**
  - **All received.**
- **Abort and HV Cards**
  - **Design nearly complete**
- **Controller**
  - **Firmware working in simulation**
  - **Card schematic done**

Personnel

- **Alan Baumbaugh (PPD/EED)**
  - System design, Control card software
- **Kelly Knickerbocker (PPD/EED)**
  - Timing card, infrastructure
- **Craig Drennan (AD/BS)**
  - Digitizer
- **Marvin Olson (AD/ID)**
  - System support
- **Cecil Needles (PPD/EED)**
  - Digitizer Firmware
- **Mike Utes (PPD/EED)**
  - Abort Card
- **Jonathan Lewis (PPD/CDF)**
  - Management
- **Stephen Pordes ~~(AD/ID)~~ PPD**
  - Wisdom and advice (solicited or otherwise)
- **Randy Keup (AD/ID)**
  - Applications programs
- **Brian Fellenz (AD)**
  - HV card
- **Jin-Yuan Wu (PPD/EED)**
  - Control Card
- **Charlie Briegel, Brian Hendricks (AD/Controls)**

Schedule

- **Beam tests starting soon**
  - **Can do extensive testing with VME readout before Controller complete**
    - Pre-production Digitizer, Controller and Abort card added in June
  - **Duplicate BLMs to compare to legacy system**
    - Tevatron: 6 at E1
    - Main Injector: 2 at MI60
  - **Develop and test software**
  - **Get operational experience**
- **July 2005: Preproduction test**
- **Install crates when old BPM electronics removed**
  - **Get host CPUs running ASAP**

Installation Schedule

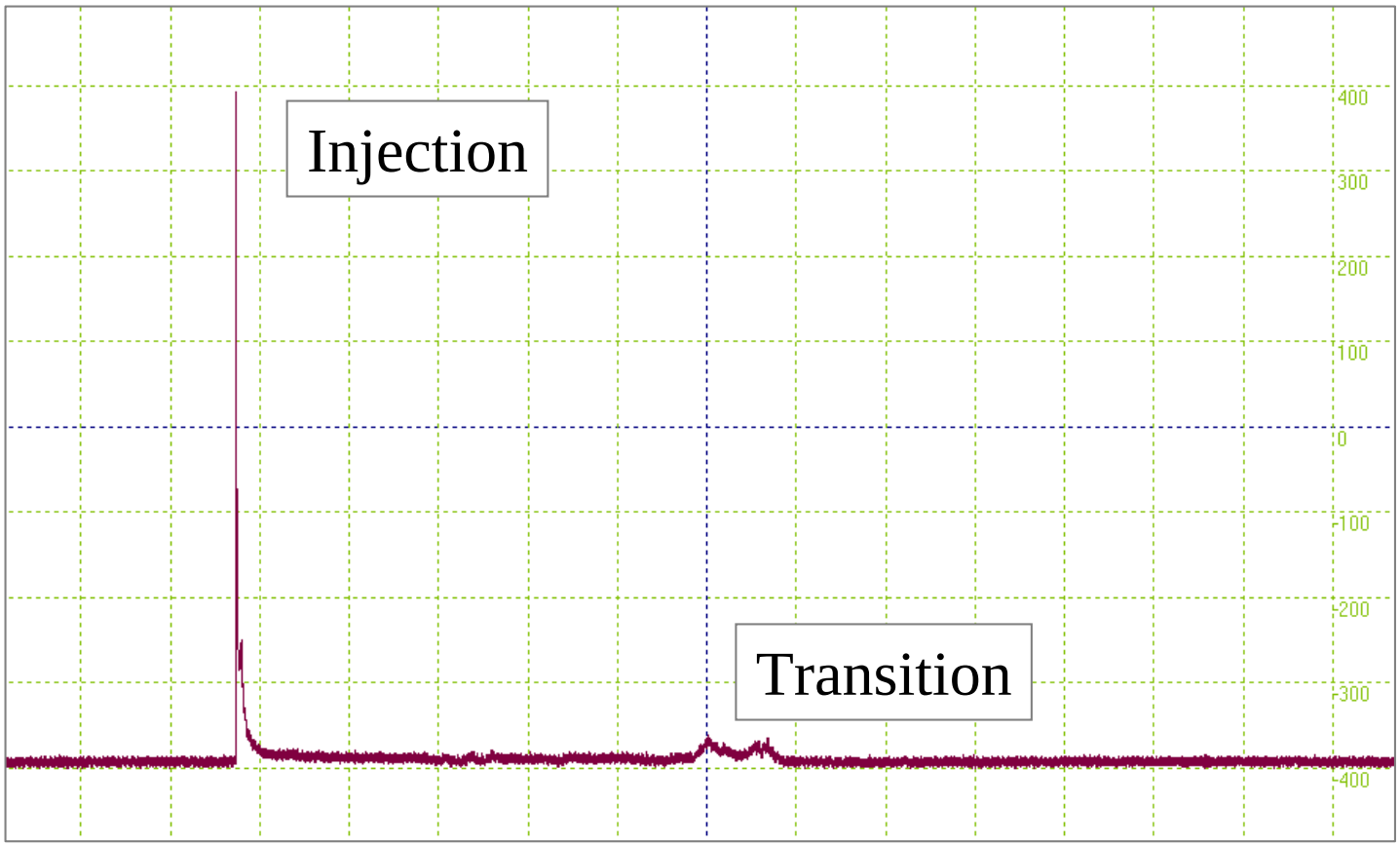
- **Modules available to install in November**
  - **Tevatron and MI**
- **Can install new system without removing old**
  - **Easy cabling changeover**
- **Can establish operations with small fraction of channels then move balance of cables**

Experience

- **Studies with 2-channel digitizer test card**
- **Understand signals and noise**
  - **Selected sites in Tevatron, MI and Booster**
- **Check calibration for Tevatron**
  - **Old system: 50nA ↔ 0.84 Rad/s (1 Rad ↔ 60nC)**
  - **New system: 50nA ↔ 56 counts (20μs bins)**
- **Explored noise suppression**
  - **Wide channel-to-channel variation**
  - **Filters**
    - Chokes for common mode
    - Resistor to increase effective integration time
  - **Running sums**

MI: LM402G full cycle

~0.2pC/div
(per 20μs)



25 ms/div

Tevatron: LMF0DT

~2pC/div
(per 20μs)

1 Rad/s DC

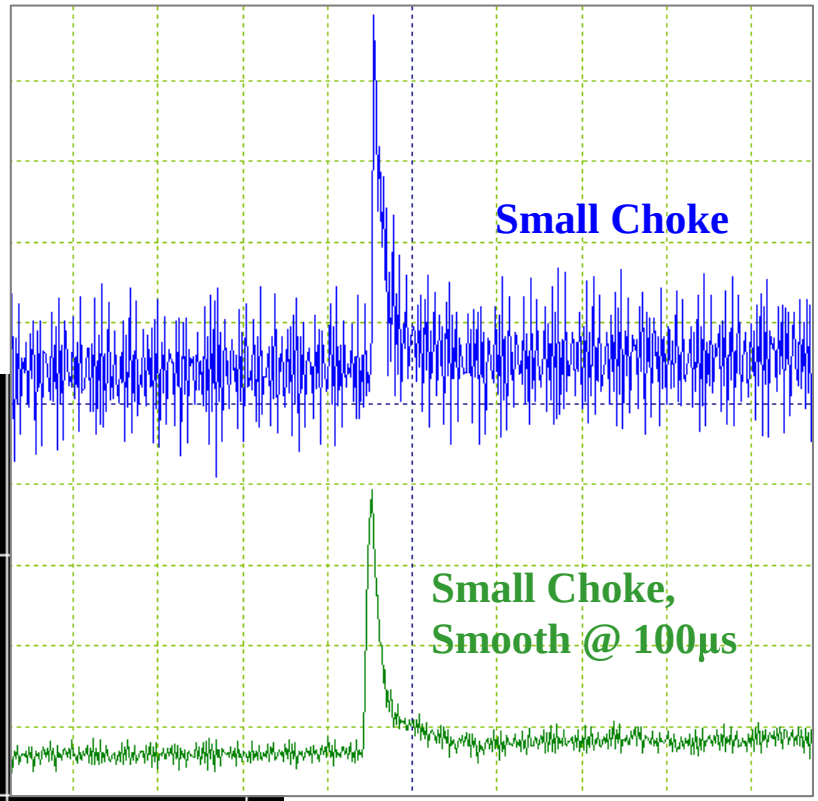
5 ms/div

Proton Injection Loss During Shot Setup 8/22/04

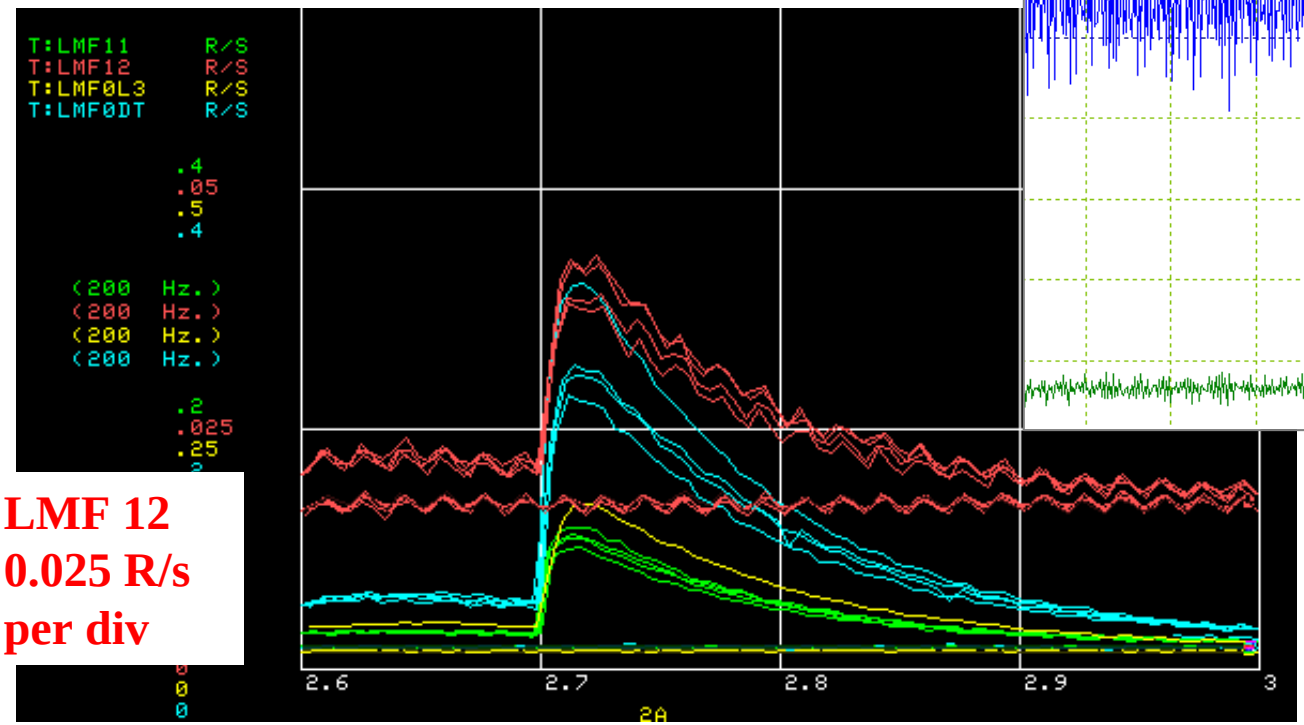
LMF12: Old and New

Losses in F-sector from 120 GeV beamline during stacking

~0.2pC/div (per 20µs)



1 ms/div



LMF 12 0.025 R/s per div

100 ms/div

Conclusions

- **In past year, we have completed most of the design work for a new BLM readout system**
- **Improved diagnostics will improve accelerator performance**
- **Greater flexibility will enable better protection of equipment**
- **Expected to be online February 2006**

Backup Slides

Custom Digitizer Card

- **4 Loss Monitor Channels**
  - **Dual Charge Integrator (Burr Brown ACF2101)**
    - Alternately integrating or being readout and reset
    - Provides continuous measurement
    - 50 kHz maximum sample rate
- **FPGA**
  - **Controls integrators**
  - **Reads ADCs**
  - **Stores readings (raw measurements)**
  - **Forms three running sums**
  - **Compares readings and sums to programmed thresholds**
    - Results sent to Abort Card
- **Raw data buffers**
  - **Running circular buffer**
  - **Triggered buffer for turn-by-turn studies**
- **Maximum 15 cards per crate**

Other Modules

- **Timing Card**
  - **Provides synchronous integration clock to digitizers**
    - External input Clock reference or internal oscillator
    - Can also be divided (e.g. AA÷2 for MI)
  - **Time stamp buffer in sync with the digitizers' raw data buffers**
  - **Decoder to receive clock events**
- **Abort Card**
  - **Receives abort info from the digitizer cards, compares against abort masks and multiplicities and makes the abort signals**
  - **One abort input for each time-range from each channel**
  - **Separate decisions for each time-range**
    - Independent masks and multiplicity thresholds
  - **Aborts are formed in < 20 microseconds**
  - **Also transmits abort data on ring-wide serial link**

Other Modules, 2

- **Controller Card**
  - **Communicates with other cards on control bus**
    - Bus master
  - **Isolates Abort functions from outside world**
    - FPGA VME slave and control-bus eZ80 access shared memory
      - Stores loss data buffers for running sums and provides to VME
      - Stores BLM thresholds and abort requirements for each machine state
    - Loads parameters into digitizer and abort concentrator cards based on machine state
- **Front-end CPU**
  - **Motorola MVME 2xxx for communication with ACNET**
- **High Voltage Card**
- **Wiener VME Chassis with low-noise power supply**

Proposed Machine States

- **Tevatron Operation**
  - Proton Studies (i.e. uncoalesced batch at 150)
  - Proton Injection
  - Activate Separators
  - Pbar Injection
  - Ramp
  - Squeeze
  - Scraping
  - HEP
- **F Sector (change mask)**
  - P2 Beam
  - P2 & P3 Beam
  - F-Sector Restore
- **Experiments**
  - CDF Silicon Biased
  - CDF Silicon Off
  - D0 Silicon Biased
  - D0 Silicon Off

Booster: LM23

~1pC/div
(per 20μs)

Raw

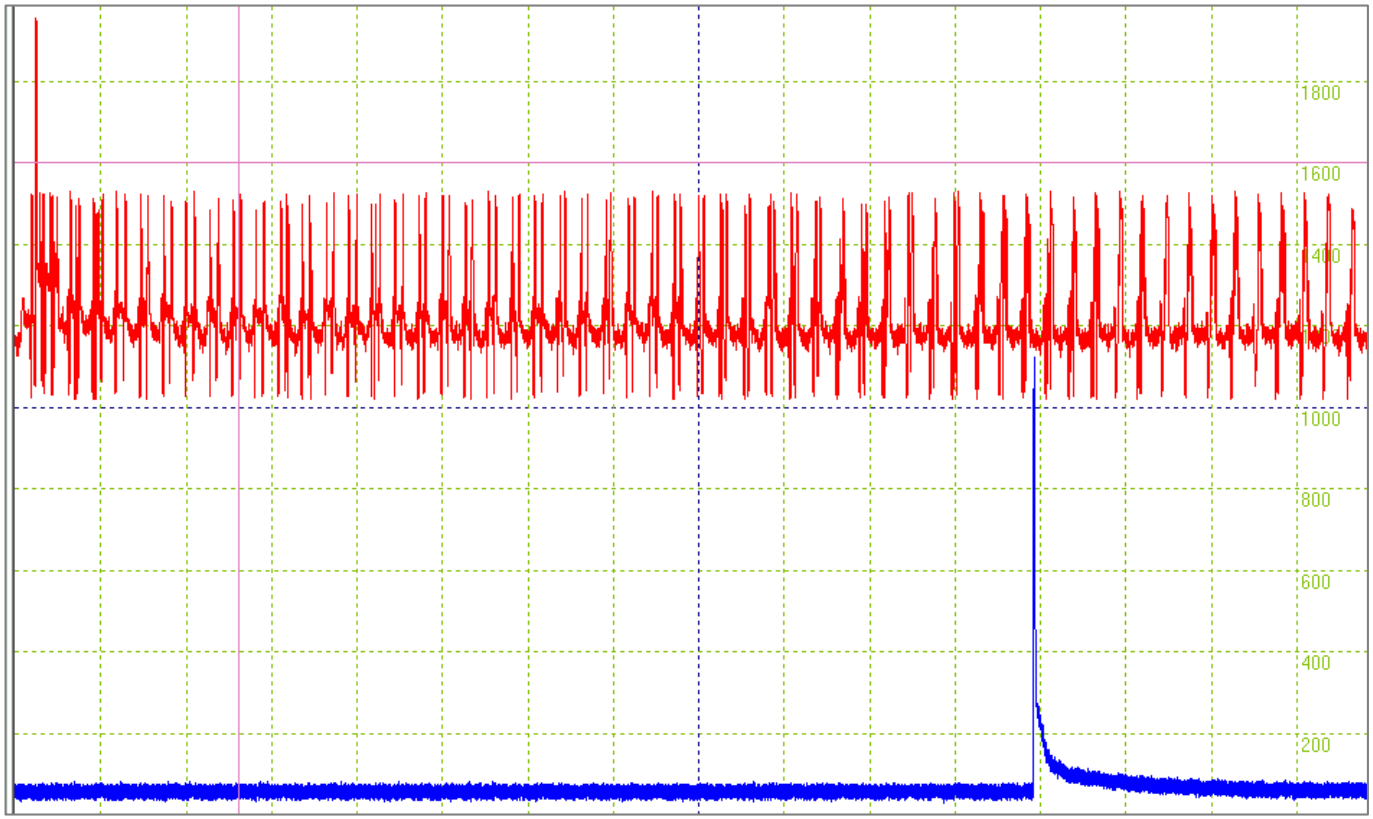
Choke

Choke+25k

1ms/div

MI: LM402G

~0.4pC/div
(per 20μs)

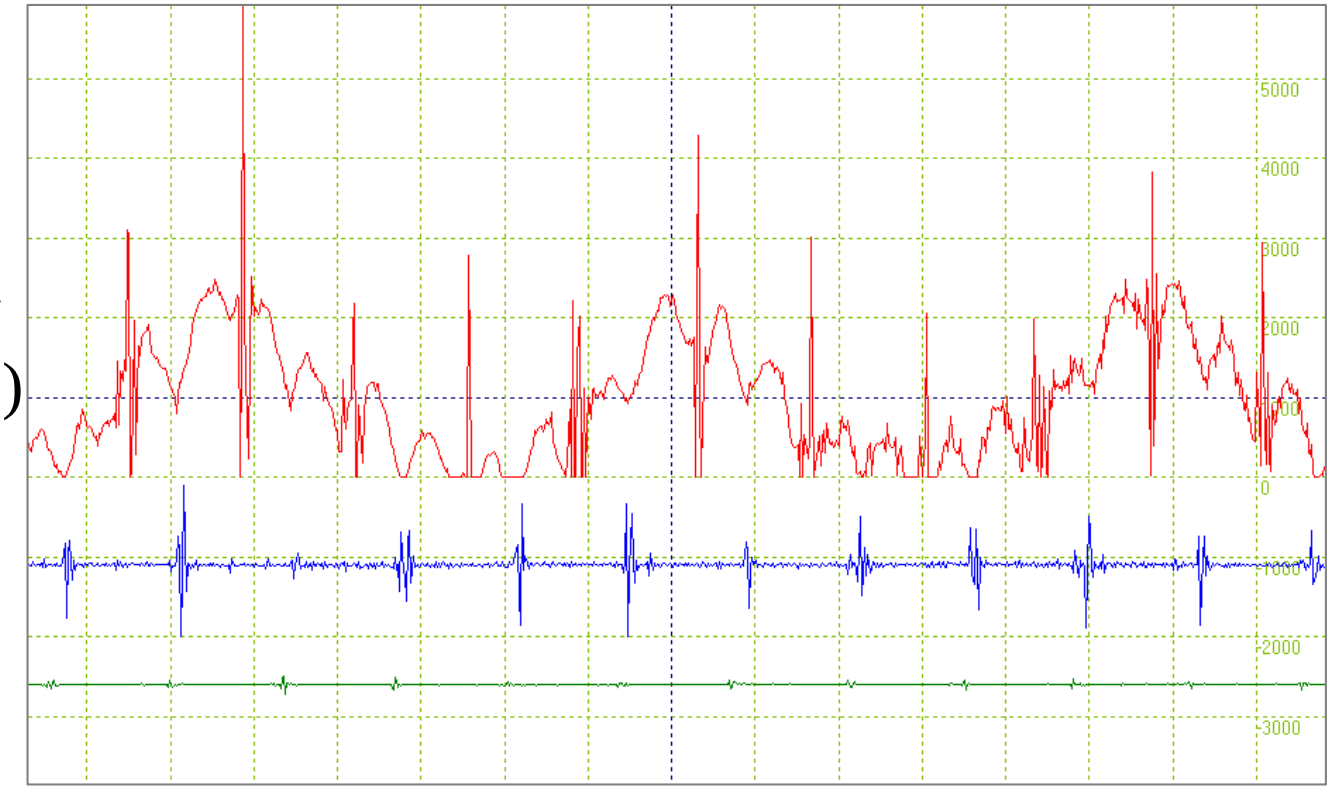


5 ms/div

- Large common-mode rejection from small choke
- Injection loss shows up cleanly

Worst Case Noise: LM322

~2pC/div
(per 20μs)



Raw

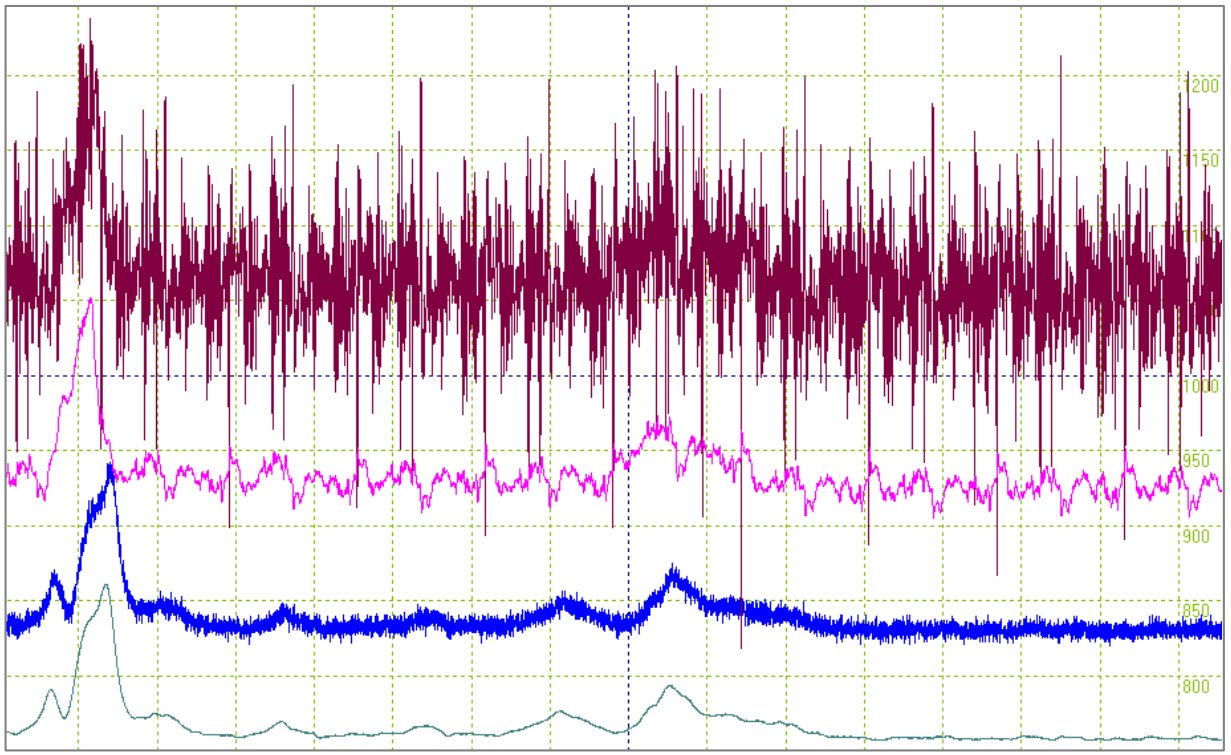
80 ft Choke

Choke+25k

1ms/div

Smoothing: LM522F

~0.1pC/div
(per 20μs)



Raw

Smooth @1ms

Small Choke +25k

Smoothed

10 ms/div